Steady turning of motorcycles

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Abstract: When driving along a circular path, the rider controls a motorcycle mainly by the steering torque. If the steering torque is low and the vehicle is moderately over-steering, a good handling feeling is perceived by the rider. In this paper, non-linear steady turning results are analysed over a wide range of forward speeds and lateral accelerations, and different 'driving zones' are identified by considering the steering torque transition speeds and steering angle critical speed. A parametric linear model of steady turning, concerning both the steering torque and the steering angle, is developed and simple parametric expressions of transition speeds and the critical speed are obtained. Steady turning tests involving different motorcycles are presented, the transition speeds and critical speed are found by linear fitting, and the characteristics of the different driving zones are investigated. The primary purpose is to determine the conditions at which the operational safety and handling of the vehicle do not impose severe demands on rider skill for control and adequate path-following properties, i.e. to identify a 'preferable driving zone'.

Keywords: motorcycle, steady turning, capsize, over-steering, under-steering

1 INTRODUCTION

The handling of motorcycles has long been of practical and theoretical interest. These two-wheeled vehicles present unique problems of stability and control, requiring continuous attention by the rider to accomplish a riding task. Because of the openness of the vehicle, the rider is vulnerable, and disturbance inputs from perceptual, aerodynamic, and roadway sources can perturb the vehicle and cause unintended arm and body control actions. Hence, the precrash safety performance of motorcycles is a significant factor in their operational use, and handling plays a more important role than it does for most other vehicles. The rider controls the motorcycle mainly by the steering torque exerted through the handlebar. Vehicle response is essentially determined by its inertial and geometric properties and by tyre characteristics [**1–4**]. Handling feeling and stability are perceived when the steering torque is low and opposite to the turning direction; capsize mode is in fact stable, and fewer corrective actions are required [**2**, **5**]. Moreover, the steady state value of the steering torque represents a bias towards or away from the input necessary for transient manoeuvres. For example, when the steady torque magnitude is small, the rider finds it easier to avoid a sudden obstacle or to perform other fast manoeuvres. The steering angle behaviour is also important. Correlations with subjective evaluations by expert test riders have long suggested that the best ratings occur for vehicles with neutral to modest over-steering properties and that, in any case, counter-steering driving may require a certain amount of skill and experience to be achieved safely [**6**, **7**].

To define and explore better the potentially important relations between turning performance and design, several researchers have proposed various tests and performance indices. Weir and Zellner [**5**] reported the results of steady state turning tests for five different motorcycles. The ratio of steering torque to roll angle was found to be a good performance index with regard to handling. The ratio of yaw speed to steering angle was also of interest with regard to steering behaviour. Complementary efforts by Rice [**4**], concerning steady state turning tests with four riders who had different degrees of road experience, revealed marked differences in driving strategies depending on

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